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Analysis of Farm Systems Models for GHG Mitigation: Leveraging Biophysical Tools to Optimize Carbon Farming Economics

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Climate change (long-term shifts in weather patterns) and global warming (phenomenon of increasing average air temperature) is the key issue global issues. Global agri-food systems emissions were 16 billion tons of carbon dioxide equivalent (Gt CO_2eq in 2021), an increase of 14 per cent since 2001. Agriculture account 13% of total GHG emission. Rice crop contributes highest to GHG emission among agriculture crops. Three important GHG from agriculture, forestry, and other land use sector are methane, carbon dioxide and nitrous oxide.

What are the biophysical models on carbon farming economics (To minimize emission)?

1. **CENTURY Model:** this is a general model of plant-soil nutrient cycling, which is being used to simulate carbon and nutrient dynamics for different climate and ecosystem conditions. The timespan is generally monthly but seasonal dynamics also can be used while analyzing the data involving the following variable
   a) Monthly average maximum and minimum air temperature
   b) - Monthly precipitation
   c) - Soil texture
   d) - Plant nitrogen, phosphorus, and sulfur content
   e) - Lignin content of plant material
   f) - Atmospheric and soil nitrogen inputs
   g) - Initial soil carbon, nitrogen (phosphorus and sulfur optional)

   The century contains two plant production submodels; a grassland/crop submodel and a forest production submodel. Through using the century model we can identify the state of degradation and based on this results we can draw the crop planting schedule for different regions and climatic conditions. Conservation tillage, rotational cropping, fertilizer management to mitigate the GHG mitigate strategies studied.
2. **Optimization Technique (linear programming or multi-objective programming):** Linear Programming as an effective tool in various decision-making problems in agriculture including crop planning, crop substitution study as it can efficiently handle a large number of linear constraints and variables simultaneously. It incorporates emissions from crop level. To optimize using the linear programming, CRAN package of linprog, Matlab software can be used involving following variable depending on the objective function and constraints equation:

   Crop area data, production, productivity, emission, and rainfall, irrigation data, and temperature data can be used. Crop area substitution while minimizing the emission from agriculture land and livestock management has been conducted using these studies and these kind studies can be expanded to regional and district level.

3. **APSIM (Agricultural Production Systems sIMulator):** APSIM is a process-based effective tool for analyzing whole-farm systems, including crop and pasture sequences and rotations, and for considering strategic and tactical planning. APSIM allows users to improve understanding of the impact of climate, soil types, and management on crop and pasture production. It is a powerful tool for exploring agronomic adaptations such as changes in planting dates, cultivar types, fertilizer/irrigation management, etc. It incorporates emissions from crop level. APSIM can simulate more than 20 crops and forests using the geographical information system at national and regional level using Soil properties, daily climate data, cultivar characteristics, and agronomic management to find out changes in crop and pasture yields, yield components, soil erosion losses, for different climate change scenarios.

   So to understand the non-linear complex interaction within agricultural ecosystem and its effect on productivity and emission, carbon sequestration studies, APSIM is suitable technique which can be used.

4. **Erosion-Productivity Impact Calculator**: It was developed to determine the relationship between soil erosion, fertilizer need and soil productivity in the United State. It incorporates emissions from crop level. This model includes weather simulation, hydrology, erosion-sedimentation, nutrient cycling, crop growth, tillage, soil temperature, economics, and plant environment control. Soil productivity is expressed in terms of crop yield; crop growth is one of the most important processes simulated by EPIC. To evaluate the effect of erosion on crop yield, the model must be sensitive to crop characteristics, weather, soil fertility, and other soil properties. From the EPIC model we can calculate the long term yield from different simulated strategies and this simulated long term yield can be used to optimize the emission level using optimization technique at simulated data. Using this model we can calculate the benefit of converting cropland to perennial grassland through valuating the carbon sequestration and plant growth.

   In all these models crop wise emission data under different climatic conditions required to optimize the emission level while maximizing the agricultural production or agricultural income, so these two models designed to estimate the GHG emission are follow:

1. **National Carbon Accounting Toolbox:** NCAT is an Australian predictive model for carbon flows in forest and agricultural systems. National carbon accounting system is designed to estimate the total amount of carbon dioxide (CO2) and other GHGs emitted or removed from studied area. FullCAM is the core model within NCAT that estimates carbon stock changes across various carbon pools due to land use and management practices. NCAT uses remote sensing based data to monitor change in land use, vegetation cover and forest biomass and simultaneously the filed survey and past land records used to access long term trend and carbon stock changes but this model doesn't considers nitrogen emissions in agricultural system.
2. **Carbon Accounting for Land Managers:** It is online calculator that can be used to estimate GHG emissions and carbon sequestration on farm scale.

Steps in Carbon Accounting for Land Managers:

2.1.Map the land areas: Area that are under control and classify them according to their land use (forest, farmland, pasture, etc.) first.

2.2.Determine the initial carbon stocks: Measure the carbon stocks at baseline in all relevant pools (soil, vegetation, etc.) so that changes in the future can be compared to it.

2.3.Execute and Record Management Procedures: Keep track of every action related to managing the land, including planting, harvesting, fertilizing, and grazing. To calculate carbon impacts, this paperwork is necessary.

2.4.Determine Sequestration and Emissions: Calculate the GHG emissions and carbon sequestration related to the documented management techniques using the relevant models and emission variables.

2.5.Observe and Document: Keep a regular eye on land-use and carbon stocks.

Conclusion

Land managers and policymakers can use a variety of biophysical models, including the CENTURY Model, APSIM, the Erosion-Productivity Impact Calculator, and optimization methods like linear programming, to study and put into practice efficient GHG mitigation plans by providing a thorough understanding of the intricate relationships that exist between agricultural practices and carbon dynamics, these models make it possible to optimize land use and management strategies in order to maximize carbon sequestration and reduce emissions.

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